LEAFY SPURGE

Biology, Ecology and Management

Publication of this bulletin was made possible with a grant from the Noxious Weed Trust Fund, Montana Department of Agriculture and the North Dakota State University Extension Service.

3832000795 MS

W-1088

EB 134
July 1995

MONTANA STATE UNIVERSITY EXTENSION SERVICE

NDSU EXTENSION SERVICE

Cooperative Extension Service UNIVERSITY OF WYOMING College of Agriculture

Leafy Spurge: Biology, Ecology and Management

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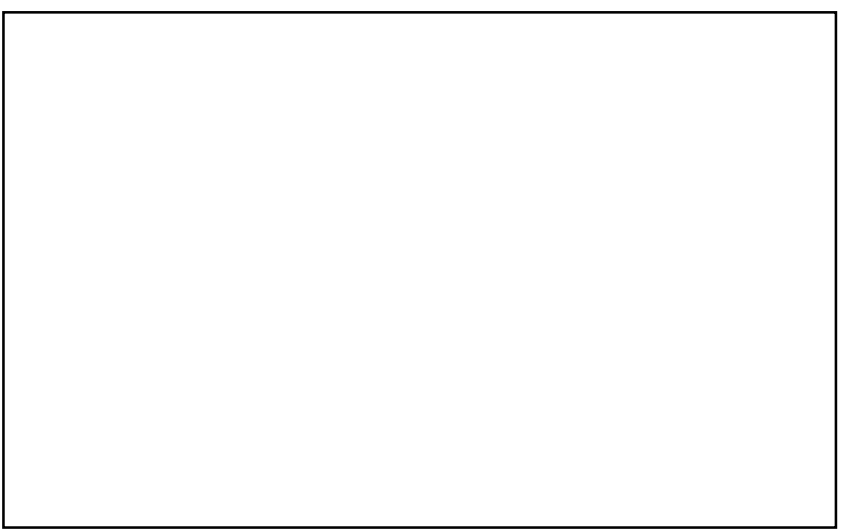

Leafy spurge is especially troublesome along waterways since seeds float downstream and produce new infestations.

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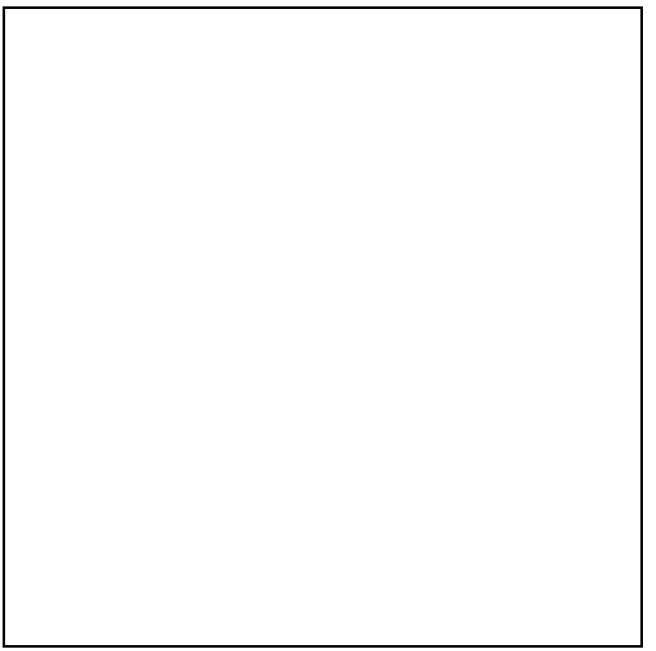


Figure 1. Leafy spurge is distinguished from plants that are similar in appearance by a white milky latex which is present throughout the plant.

Leafy spurge (*Euphorbia esula* L.) is a deep-rooted, long-lived perennial weed that is native to Eurasia and is extremely difficult to control. In North America, leafy spurge is highly competitive and can displace native vegetation, often forming pure stands. Livestock carrying capacity of infested land is near zero because forage production is reduced and because cattle and some wildlife will not graze in infested areas.

Loss of plant diversity, loss of wildlife habitat, reduction in land values and legal responsibilities for managing the weed are additional liabilities of leafy spurge. Leafy spurge is also a serious problem in cropland, where herbicide rates required for effective control are higher than labels permit. Over 2.7 million acres are infested, mainly in the Northern Great Plains and the prairie provinces of Canada. Economic losses in North Dakota alone exceed $14.4 million per year.

Although leafy spurge is spreading rapidly in other areas, including Montana and Wyoming, the number of infested acres and the rate of spread declined in parts of North Dakota between 1982 and 1992 as a result of intensive management efforts. However, continuing intensive integrated management will be nec-

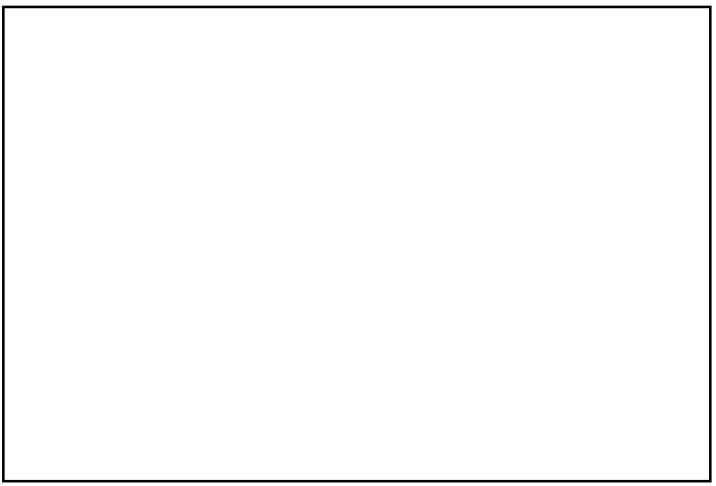


Figure 2. The inconspicuous true flowers of leafy spurge are surrounded by showy yellow-green bracts.

essary to prevent re-invasion and to reduce remaining infestations. Control of leafy spurge is possible, but only with aggressive and continuing efforts. County weed offices and the Extension service will provide assistance in designing integrated control programs.

BIOLOGY AND ECOLOGY

Identification

Leafy spurge stems are pale green or blue-green and without hairs. Stems are 16 to 32 inches tall and grow in dense patches. The narrow, hairless leaves are alternate on the stem. When the plant is injured, a milky latex sap flows from the injury (Figure 1). The small flowers are green and inconspicuous, but are surrounded by a pair of yellow-green heart-shaped leaves (bracts) which are often mistaken for flowers (Figure 2).

Life Cycle

Leafy spurge begins growing in early spring from buds on the crown (the junction between root and stem) and roots (Figure 3), as well as from seed. New growth from rootstock usually begins in late April in northern climates, giving leafy spurge a competitive advantage as one of the first plants to emerge. Peak period of seed germination is from late May to early June in northern climates, but some germination can occur any time adequate moisture is available.

Yellow-green bracts develop on stems in May or early June in the northern climates, giving the plant the appearance of “blooming.” However, the small,

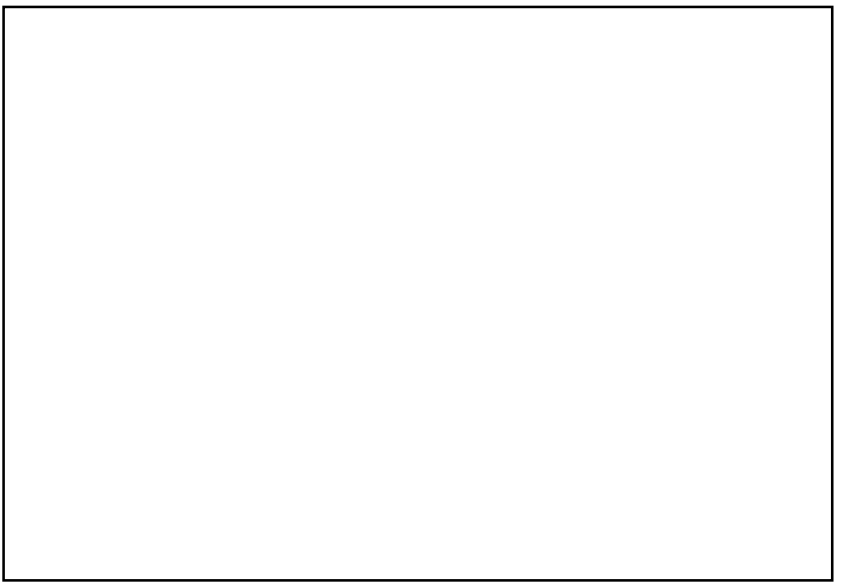


Figure 3. Leafy spurge roots have numerous vegetative buds which contribute to the spread and persistence of the weed.

green flowers develop about two weeks later. Flowering is usually completed by mid-July. Seeds develop for 20 to 30 days after flowering. (Calendar dates will vary with climate and geographic location.) Leafy spurge becomes dormant in some areas in late summer, but growth can resume in the fall. Summer dormancy does not occur in some regions, or in wet, cool years.

Seeds and Seedlings

Each flower produces a lobed capsule containing three seeds (Figure 4). When the stem matures, the capsules explode, projecting seeds up to 15 feet. Each flowering stem produces an average of 140 seeds. Flowering and seed production can occur throughout the summer if soil moisture is available. Part of each crop of leafy spurge seeds can remain dormant and viable for as long as eight years. They remain dormant even longer if seeds are deeply buried. Temperatures from 68°F to 86°F are optimum for seed germination.

In the absence of competition, seedling roots can penetrate to a depth of three feet and spread laterally 40 inches in four months By the second year, plants are well established (Figure 5). Seedlings develop stem and root buds about 12 days after emergence with new shoots developing rapidly from these buds if the main shoot is injured or removed. Seedlings rarely flower the first year.

Figure 4. Leafy spurge plants have lobed capsules which contain one to three seeds. The capsules explode when dry, projecting seeds up to 15 feet from the plant.

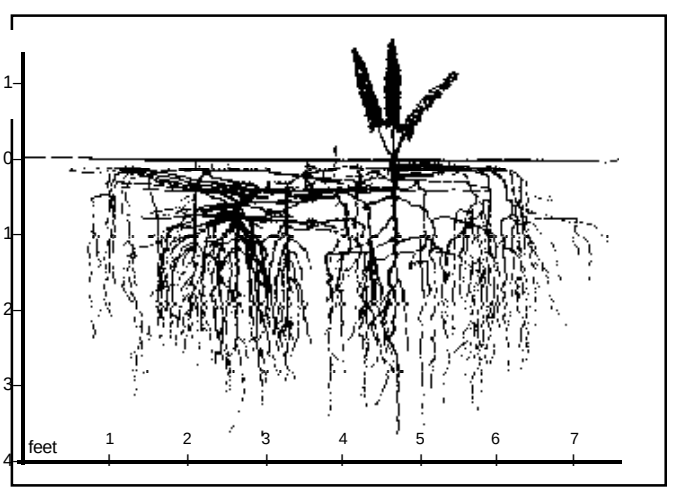


Figure 5. Root system of a two-year-old leafy spurge plant.

Shoots

Shoots develop from leafy spurge's numerous stem and root buds as well as from seeds. Stem buds cause branching of stems, while new shoots develop from root buds when older shoots are removed or the crown is damaged (Figure 3).

Roots

The root system is comprised of both vertical and horizontal roots. Main vertical roots can grow to depths of 26 feet. Horizontal roots, which grow near the soil surface, can extend 15 feet per year from the parent plant. Each root bud is capable of producing a new, independent plant. Root buds have been found at depths of ten feet or more. The depth, extent and thick corky bark of the roots enable leafy spurge to survive during periods of drought, grazing or herbicide applications. The roots contain a large food reserve capable of sustaining the plant for years and can provide the energy needed for new shoots to emerge from buds after chemical or mechanical treatments. The deep and extensive root system makes leafy spurge very difficult to control.

Dispersal

Leafy spurge seeds are spread several ways. The seeds float on water, often resulting in new infestations along ditches, rivers and in areas that are periodically flooded. Seeds can be spread by animals in the mud on their feet or are eaten by sheep, goats, rodents or birds and then deposited in dung. Seeds and sometimes root pieces are widely spread as contaminants in crop seed, feed grain or hay and on vehicles and equipment.

Habitats

Leafy spurge grows in a variety of habitats ranging from flood plains and river banks to grasslands, ridges and mountain slopes. It is found on both dry and moist sites and in climates that are either hot or cold. It is found on abandoned cropland, pastures, rangeland, roadsides and waste areas, and often dominates bottomlands. The weed is found less frequently on top slope, summit and shoulder slopes. The species will thrive on many soil types, especially after disturbance.

Distribution

Leafy spurge is found worldwide except in Australia. It has been found as far north as Scandinavia and as far south as Italy and Spain. In North America, it is widespread throughout the United States and southern Canada (Figure 6).

Figure 6. (Not available on electronic media) Distribution of leafy spurge in the United States and Canada in 1994. U.S. counties and Canadian census divisions reported presence or absence, not actual infested areas. Local boundaries shown for the provinces of British Columbia, Alberta, Nova Scotia, New Brunswick and Prince Edward Island coincide with county or municipality boundaries. Local boundaries shown for Saskatchewan, Manitoba, Quebec and Newfoundland are census divisions. Data were provided by the USDA-APHIS-PPQ Cooperative Agricultural Pest Survey (CAPS) and Canadian cooperators. Map by Diana Cooksey, Montana State University Department of Plant, Soil and Environmental Sciences.

MANAGEMENT

Successful management of leafy spurge requires the use of all available control methods. Preventing invasion by leafy spurge is the most effective management strategy. Avoid importation of machinery, feed or livestock that might be carrying leafy spurge root pieces or seeds into uninfested areas. Conduct annual, on-the-ground weed searches to spot any new infestations early, while control is still feasible. Preventing importation of the weed into uninfested areas as well as monitoring, mapping and managing existing infestations is important in good land stewardship and leafy spurge control. In many states, including Montana, North Dakota and Wyoming, leafy spurge is designated a "noxious weed," meaning land owners or managers are legally responsible for its control.

Leafy spurge control must be considered a long-term management program. It is important to remember that **no single management practice or treatment will eradicate this weed.** Annual monitoring and a combination of control methods is essential. Four methods are used to manage leafy spurge: physical control, plant competition, biological control and chemical control.

Physical Control

Physical control of leafy spurge is primarily by cultivation. Mowing and burning are also used, but are less successful and should be combined with herbicide treatments.

Cultivation

Cultivation is used on cropland, where few other options for control are available. There are generally two types of tillage programs for leafy spurge control: intensive throughout the growing season and fall-only cultivation.

Intensive tillage programs should begin in the spring, two to four weeks after leafy spurge emerges. Use a duckfoot cultivator and till four inches deep (Figure 7), repeating every three weeks until the soil freezes in the fall, for one to two growing seasons. The cultivation schedule should not be interrupted because leafy spurge resprouts quickly. Pieces of roots as small as $^1/_2$-inch long and $^1/_{10}$-inch diameter may produce new shoots. **Care should be taken not to transport root pieces on machinery into uninfested portions of the field or other areas.** Fall-only cultivation should be done once or twice when leafy spurge regrowth is three to six inches tall for three years. Fall-only cultivation allows crops to be grown during the season, limits organic matter degradation and reduces soil erosion when compared to season-long cultivation. Cultivation integrated with her-

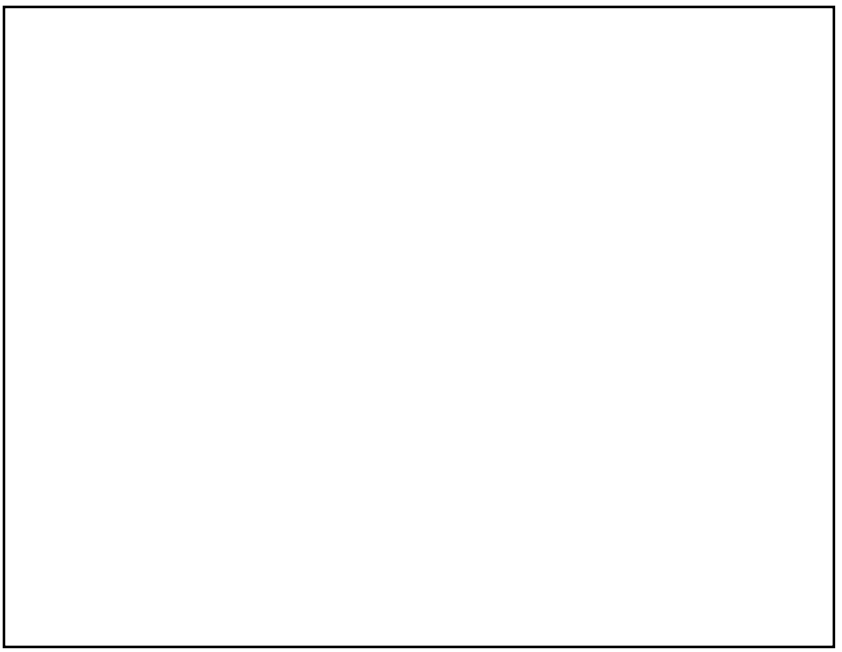


Figure 7. Intensive cultivation will control leafy spurge. However, it is often not feasible because of rough terrain and soil erosion potential on rangeland sites.

bicides enhances leafy spurge control. Herbicides such as Roundup® should be applied at label rates at least seven days before the first fall cultivation.

Mowing and Burning

Mowing and burning are ineffective for reducing leafy spurge infestations, but may provide uniform regrowth for more effective herbicide treatment. For best control, allow at least five weeks of regrowth before herbicide application. Mowing will reduce seed production if repeated every two to four weeks during the growing season, but will provide little long-term control. Mowing and/or herbicide application combined with applications of nitrogen fertilizer to stimulate grass growth does not control leafy spurge better than herbicides applied alone.

Burning can increase visibility of leafy spurge plants and can improve herbicide spray coverage by eliminating old stems and ground litter. Burning combined with herbicide applications does not increase control, but may reduce leafy spurge seed viability. Prescribed burning can be hazardous and should be conducted only by professionally trained personnel.

Figure 8. The ten-feet-deep excavation at left shows only a part of a well-established leafy spurge plant's root system. It is the network of roots close to the surface as shown in Figure 5 that compete with other plants, but these deep roots allow the plant to survive years of drought.

Pulling by Hand

Pulling leafy spurge by hand is usually ineffective, even for small isolated patches, because of the depth of the root system (Figure 8) and the large number of root buds. However, it may be possible to hand pull a few plants that are in their first year of growth. Early detection and hand pulling is especially important where control options are limited, such as in riparian areas.

Plant Competition

Some perennial grass species can effectively compete with leafy spurge, continually depriving it of moisture and nutrients. Careful management of grazing livestock can enhance the competitiveness of grasses.

Reseeding

Reseeding rangeland with a mixture of grass and shrub species may provide a more competitive environment than reseeding with any single species. Plant

early-germinating species to compete with leafy spurge seedlings for early season moisture and include species that grow late in the season to compete with fall regrowth of leafy spurge. When one species matures or enters its dormant phase, another should be starting its active growing phase to continue the competition for moisture and nutrients. Where the roots of one species stop in the soil profile, the roots of another, deeper-rooted species can compete for deep soil moisture and nutrients.

Several grass species have been evaluated for establishment and production in leafy spurge-infested areas. The most competitive grasses tested are: 'Bozoisky' Russian wildrye *(Psathyrostachys juncea*) and 'Luna' pubescent wheatgrass (*Agropyron intermedium var. trichophorum),* both tested successfully in Wyoming; 'Rebound' smooth brome (*Bromus inermis),* 'Rodan' western wheatgrass (*Pascopyrum smithii),* 'Manska' pubescent wheatgrass and 'Arthur' Dahurian wildrye (*Elymus dahuricas)* all tested in North Dakota; and little bluestem (*Schizachvrium scoparium),* which was evaluated in Minnesota. The effectiveness of species varies by region, so check with the Natural Resources Conservation Service (formerly the Soil Conservation Service) for their Plant Materials Center recommendations of the species best adapted in your area.

Generally, Roundup® or Roundup® plus 2,4-D applied once during June and repeated in July will control leafy spurge prior to grass seeding, allowing the grasses to establish in mid-August (Table 1). Timing of seeding will vary depend-

Table 1. Leafy spurge control and forage production in Wyoming field trials for two grass species.

Grass species (variety)[1]	Grass stand[2]		Leafy spurge control		Number of grass plants		Production of air dry grass	
	Tilled	No-till	Tilled	No-till	Tilled	No-till	Tilled	No-till
	%		%		per 20 ft of row		pounds per acre	
Pubescent wheatgrass (Luna)	96	94	99	96	37	28	3245	2670
Russian wildrye (Bozoisky)	96	80	96	89	54	25	1203	1114
Least significant difference at 0.05[3]	4	4	ns	ns	7	7	301	301

[1]Grasses seeded August 8, 1989.

[2]Evaluations June 22, 1993. Grasses harvested September 28, 1993.

[3]Comparison of variety means is valid between tilled and no-till.

ing on location and grasses used, but late summer seeding should be done only when good moisture is available. Late summer plantings should be done six to eight weeks before a killing frost to allow time for grasses to properly establish.

Grazing Management

Grazing animals can help control leafy spurge by increasing the competitiveness of desirable plants through timing of grazing and selective removal of the weed. When grasses are grazed, they are temporarily weakened and plant competition is altered in favor of leafy spurge. Similarly, when leafy spurge is grazed, the advantage can shift to the grasses. Grasses should be grazed when they have produced seedheads or are mature and not during periods of active growth. Conversely, leafy spurge should be grazed sooner, to minimize flower and seed production. It must be grazed often enough and at sufficient stocking rates to deplete root reserves over time, reducing the competitiveness of the leafy spurge.

Different species of grazing animals select different groups of plants. Combinations of grazing species can be used to alter plant communities. Cattle tend to prefer grasses and over time forbs (herbaceous, non-woody plants, which includes most weeds) will increase in a plant community grazed by cattle. In contrast, sheep tend to graze forbs while goats browse woody plants. Over time, grasses tend to increase in a plant community grazed by sheep or goats (Figure 9). Elk and deer tend to graze grass and browse, respectively. However, each grazing species will use all three groups of plants seasonally, heavily at times. It is essential to monitor desirable plant species regularly when using grazing ani-

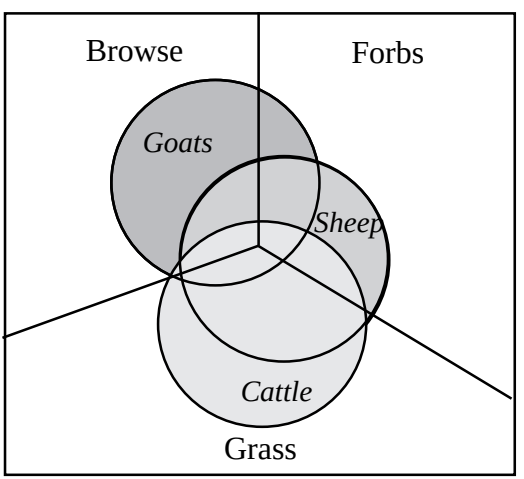


Figure 9. Average dietary overlap between cattle, sheep and goats.

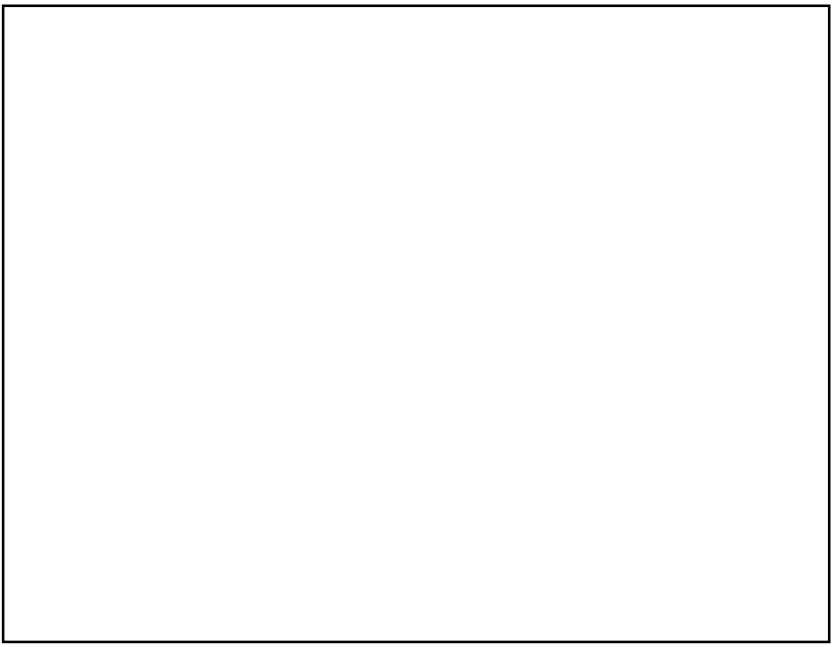


Figure 10. Landowners observe the effects of cattle grazing (right) and sheep grazing (left) on land infested with leafy spurge.

mals to manage leafy spurge. Species consumed by sheep or goats will depend on climate, season, prior dietary experience and geography. It may take three to ten years or even longer, to shift the plant community from leafy spurge to grasses—depending on species, environment and other factors (Figure 10). Leafy spurge will not be completely eradicated by grazing management. Even if sheep or goats are used to graze leafy spurge, grazing management must be considered a long-term management system to suppress infestations.

Sheep

Generally, sheep graze forbs (including leafy spurge) more in spring and summer when plants are young and succulent, but will select grasses more in fall and winter, competing more directly with cattle. When leafy spurge is grazed, the regrowth is often succulent and sheep will continue to select it into early fall. Dietary overlap between sheep and cattle ranges from about 30 percent during spring and summer to 70 percent during fall and winter. If sheep are leased, a contract of at least five years might be necessary for the project to be feasible for the sheep producer. An intensive grazing system that includes a minimum of two

grazing periods in a season, each followed by a rest period to allow grass regrowth, is more effective than season-long grazing. Stocking rates vary with leafy spurge density, terrain and rainfall. Approximately three to six head per acre of leafy spurge per month (or one to two ewes with lambs per acre per summer) may be sufficient. Adjust the stocking rate as needed to prevent blooming. Sheep that have not previously grazed leafy spurge may require a five- to ten-day adjustment period.

Sheep have been used with positive results in conjunction with insect biocontrol agents in the genus *Aphthona* (the flea beetles). Sheep are grazed once in spring and again in fall. This schedule avoids disturbing adult beetles when they are laying eggs and feeding.

Keep the following guidelines in mind when controlling leafy spurge with sheep:

1. Use rotational grazing strategies that allow leafy spurge to be grazed often enough and at sufficient stocking rates to weaken the plant. Grazing periods should be timed to minimize stress to desirable vegetation, especially during stem growth and flowering of grasses. Monitor desirable plant species regularly.

2. Grazing should begin in early spring when leafy spurge plants are two to six inches tall. Breeding schedules should be timed so lambing is completed by May if ewes are used in the program. Wethers may also be used—they range farther and sometimes experience fewer problems with predators.

3. Pasture rotations should be scheduled to prevent leafy spurge from producing seed. When “the yellow is gone” (the yellow-green bracts), the sheep can be moved to other leafy spurge patches. Once in late spring and again in early fall may be sufficient. Herders or portable electric fencing may be necessary in many operations.

4. Sheep grazing leafy spurge plants which have mature seed should be corralled for at least a week to pass seeds from their digestive tracts before they are moved to an uninfested area. Transportation of sheep from leafy spurge-infested areas to uninfested areas should be minimized to prevent transport of seeds in their wool.

5. Check with predator management professionals before deciding to use sheep—losses to predators may offset gains in weed control.

Goats

The relative ability of goats and sheep to control leafy spurge varies with the kind of plant community. For example, sheep might be used in areas where preserving woody vegetation is important. Goats will browse woody species in ad-

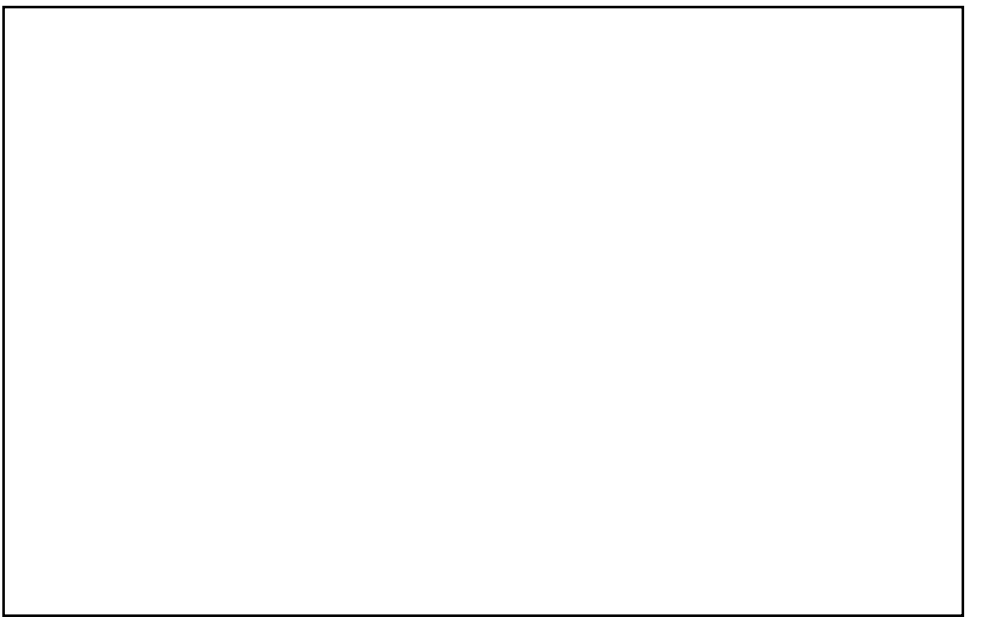
dition to forbs and grasses. Goats are best used in areas where terrain is too rough for sheep or where burrs or other plant species that are problematic for sheep are plentiful. Monitor desirable species regularly, especially woody species. Stocking rates vary with terrain, leafy spurge density and rainfall. Twelve to 16 Angora goats per acre of leafy spurge per month or three to four goats per acre of leafy spurge for four months may be sufficient. Although goats are sometimes better suited to a particular area, they require more management than sheep and markets may be more limited. Herbicide application (Tordon® at one quart + 2,4-D at one quart product per acre) in mid-September following fall grazing by goats has provided good control. Allow three to four inches regrowth before applying herbicides.

Cattle

Cattle will not graze leafy spurge and will not control this weed. The milky latex found in leafy spurge is a digestive tract irritant to cattle when ingested and contact can result in lesions around the eyes and mouth. Improper timing of grass grazing by cattle may increase leafy spurge infestations. Cattle should graze leafy spurge-infested pastures either before grasses begin their active growing phase or after grasses have produced seedheads. In programs that include cattle and sheep, cattle can harvest the grass before sheep are placed in the area which will enable sheep to remove leafy spurge more quickly and efficiently. Avoid allowing grazing of actively growing grasses in spring. Cattle can also be allowed to harvest grass late in summer before sheep are placed in the area to graze leafy spurge regrowth.

Biological Control

In countries of its origin, leafy spurge is a member of the native plant community, controlled by insects, plant diseases, plant competition, intensive grazing and other environmental factors. These controlling factors were left behind when the weed was transported to North America, resulting in its unchecked spread. Insects that attack the weed in its native lands have been collected, tested for feeding preferences and released on leafy spurge in North America. Only biological control agents that did not feed on crop and ornamental plants in the feeding preference trials have been approved for release in the U.S. and Canada. Plant pathogens that attack leafy spurge are also being tested. These biological control agents—or biocontrols, as they are called—will never completely eradicate the weed, but they may reduce weed populations over a period of years (Figure 11).



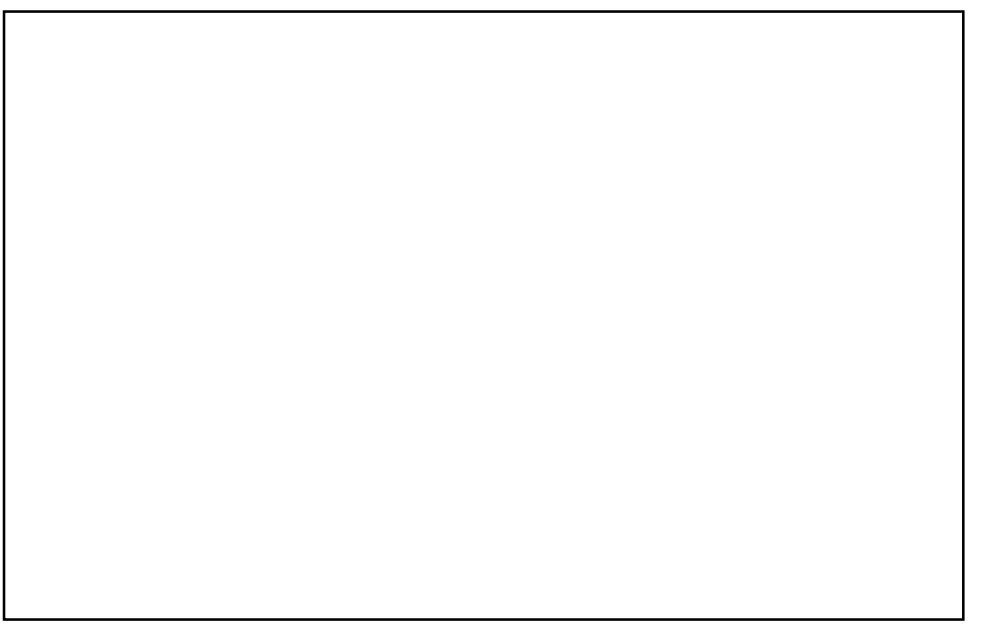


Figure 11. Top photo: Leafy spurge infested site (N-Bar Ranch, Grass Range, Montana). Bottom photo: Same site, four years after release of Aphthona nigriscutis beetles.

Insect Biocontrol Agents

A number of species of insect biocontrol agents of leafy spurge have been approved for introduction into the United States. At this time, the most effective and well-established biocontrol agents appear to be several species of root- and foliage-feeding beetles in the genus *Aphthona* and one species of stem- and root-boring beetle, *Oberea erythrocephala*. **Appendix 1 contains information on biology, habitat requirements, collection and release suggestions for each of these biocontrol agents**.

Collecting, Handling and Releasing Insects:

The following suggestions may help ensure successful collection and establishment of biocontrol agents:

1. Before collecting biocontrol agents, determine habitat requirements for each species (Appendix I) and locate release sites that meet those requirements. Avoid sites with high ant and grasshopper populations. Insects should be released in areas free from grazing, herbicide or insecticide applications and general traffic. The initial release site should be protected for up to 10 years; secondary sites may not need as much protection. Grazing is possible on secondary sites if timed when biocontrol agents are not present on foliage (Appendix I).

2. Collections should be made with minimum stress to the insects. Hardy insects such as beetles can be collected by passing a sweep net through the upper portions of the leafy spurge plants eight or 10 times and then dumping the contents into a container.

3. Release biocontrol agents as quickly as possible. If the insects are to be moved more than 50 miles or held longer than a few hours, the biocontrol agents should be sorted out so that detrimental or predatory insects, spiders, ants, mites, etc., will not accompany them to the new location or kill them in transit. The agents should be kept cool during transport by placing them in a cooler with refrigerated (not frozen) coolant packs.

4. Release biocontrol agents by sprinkling over a small area, usually 10 to 15 square yards, on a leafy spurge infestation of moderate density. Avoid tall, dense stands of plants that sometimes provide too much shade and high humidity. Release insects during the cool parts of the day.

5. Permits are required to transport biocontrol insects or pathogens across state or provincial borders. In Montana and Wyoming, permits are obtained from the state Department of Agriculture and in North Dakota from the USDA Animal and Plant Health Inspection Service.

Pathogen Biocontrol Agents

Plant diseases can also be used to manage weeds. Several promising bacteria and fungi that attack leafy spurge roots, crowns and seedlings have been identified and are being investigated. The integration of pathogens with other control methods also is being investigated.

Chemical Control

For best results, chemical control should be used as part of a systems approach for managing leafy spurge. Herbicide treatment programs that use annual applications provide the best long-term control strategy. **Do not skip a year** until control reaches 90 percent or more—otherwise leafy spurge will reinfest rapidly (Table 2). For assistance in selection and use of herbicides, contact your county weed supervisor or Extension agent.

Small Patches

When leafy spurge is confined to small, well-defined areas, herbicide treatments should begin immediately to prevent seed production and spread of the weed. Treat an extra 10 to 15 feet around leafy spurge patches to control spreading roots and seedlings. Neither biological control nor grazing should be used to manage small patches because these methods work slowly, will not prevent seed production (in the case of biocontrol) and will not eradicate the weed. When patches are small and isolated, **it is possible to eradicate them** with herbicides. This effort should be given highest priority. If seeds have been produced the site should be monitored for a minimum of eight years.

Table 2. Longevity of leafy spurge control if an infestation is not retreated.

Control 12 months after last treatment	Years without retreatment		
	1	2	3
	% control		
95% or more	85	70	< 20
80%	60	< 20	0
70%	< 30	0	—
60%	20	0	—

Table 3. Leafy spurge control in pastures and rangeland with herbicides generally applied annually, during the true-flower growth stage

Year 1		Years 2-4		Months after initial treatment			
Herbicide	**Rate**	**Herbicide**	**Rate**	**12**	**24**	**36**	**48**
	(product/ acre)		**(product/ acre)**	**(% control)**			
Tordon 22K	1 quart	Tordon 22K	1 quart	65	70	75	90
Tordon 22K	2 quarts	—	—	75	20	0	—
Tordon 22K	4 quarts	—	—	95	80	75	25
Banvel	2 quarts	Banvel	2 quarts	55	85	95	—
2,4-D[1]	2 quarts	2,4-D[a]	2 quarts	20	30	35	20
Tordon 22K	1 pint	Tordon 22K	1 pint	40	50	40	50
Tordon 22K+ 2,4-D	1 pint + 1 quart	Tordon 22K+ 2,4-D	1 pint + 1 quart.	50	65	75	85
Tordon 22K+ 2,4-D	1 quart + 1 quart	Tordon 22K+ 2,4-D	1 quart + 1 quart	70	75	80	95
Roundup + 2,4-D[2]	1 pint + 1 pint	Tordon 22K +2,4-D	1 pint + 1 pint	75	90	—	—
Roundup	1 quart	———	——	80	10	—	—

[1]2,4-D applied twice per year in the spring and fall, based on 4 pounds active ingredient/gallon concentrate.

[2]Applied during the seed-set growth stage in late June early July.

Pasture and Rangeland

Tordon 22K® (picloram) is the most effective herbicide for controlling leafy spurge. For small, isolated patches only where annual retreatment is not feasible, Tordon 22K® at one gallon of product per acre will give 90 percent or more leafy spurge control the first year after treatment (Table 3). Control will decline gradually to approximately 70 percent three years after treatment and more rapidly thereafter. This application rate is not labeled for and should not be used on large infestations (infestations larger than a half-acre).

Research at North Dakota State University has shown that a cost-effective treatment for leafy spurge control is a tank mix of Tordon 22K® at one pint per

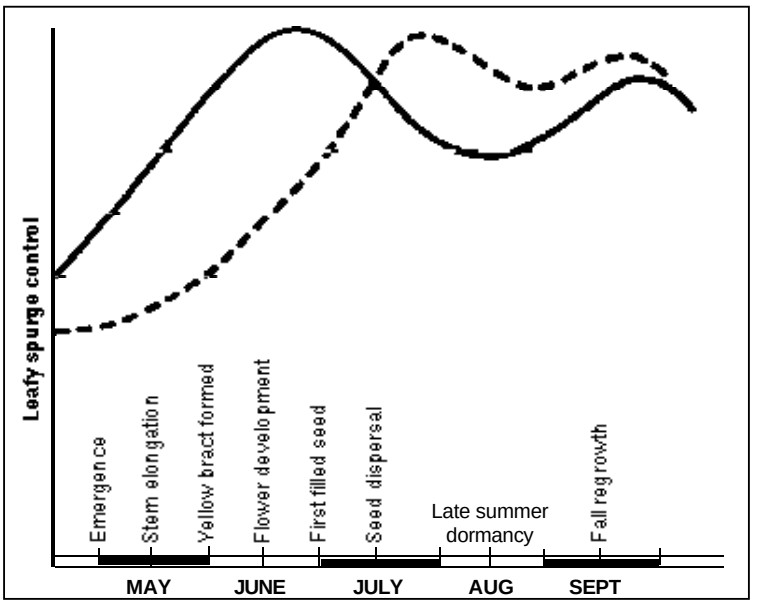


Figure 13. Susceptibility of leafy spurge to 2,4-D, Banvel®, Roundup® + 2,4-D, or Tordon 22K® (dotted line) and to Roundup® alone (solid line) when applied at various times during the growing season.

acre combined with 2,4-D (four pounds active ingredient per gallon concentrate), at one quart per acre applied annually during true flowering, approximately two weeks after appearance of the yellow bracts (Figure 13). This treatment has provided 85 percent leafy spurge control after four annual applications (Table 3) and was the most cost-effective treatment for leafy spurge. Fall application of this treatment may not effectively control leafy spurge.

Tordon 22K® at one quart per acre with 2,4-D at one quart per acre provides greater control, does not require retreatment as frequently, but is more expensive compared with Tordon 22K at one pint plus 2,4-D at one quart. This treatment can be applied either during true flowering or in the fall (Figure 13). An economical management option is to apply Tordon 22K at one quart per acre with 2,4-D at one quart per acre the first year, followed by Tordon 22K at one pint per acre plus 2,4-D at one quart per acre for three consecutive years.

Banvel® (dicamba) may provide intermediate levels of leafy spurge control in pastures and rangeland, but annual treatments with dicamba are not cost-effective.

Roundup® plus 2,4-D (glyphosate + 2,4-D) will provide season-long leafy spurge control, but there is a risk of grass injury, especially when applied in the fall. A single treatment of one pint Roundup plus one pint 2,4-D per acre applied during early seed-set growth stage (Figure 13) will provide at least 75 percent leafy spurge control with 0 to 10 percent grass injury. **This treatment should**

not be applied to the same area for two consecutive years because grass injury could be severe. Applications of Roundup with 2,4-D should be followed by Tordon plus 2,4-D during the flowering stage the second year.

2,4-D ester or amine (four pounds active ingredient-per-gallon formula) at one quart per acre will give short-term control of leafy spurge top growth. Forage production can be increased when this treatment is applied annually in spring. Higher rates of 2,4-D do not provide significantly better control.

Control in Trees

Amine formulations of 2,4-D at one quart per acre may be used to control leafy spurge top growth under trees. Avoid contacting tree foliage and green bark of young trees with either direct spray or spray drift.

Roundup® at one quart per acre when grasses are dormant may give 80 to 90 percent leafy spurge control. Without retreatment, control drops to about 10 percent the second year. Treatments made prior to mid-July have not given good leafy spurge control. Roundup® is non-selective at higher rates and will kill grasses and other vegetation. Avoid contacting tree foliage and green bark of young trees with either spray or drift.

Roundup® combined with 2,4-D (one pint each) can be used under trees to control leafy spurge and decrease the amount of desirable and vegetation injury caused by Roundup alone. Roundup with 2,4-D can be applied two to four weeks earlier than Roundup alone to obtain good control.

Control Near Water

2,4-D formulations labeled for use near water at one quart per acre applied in mid-June will prevent seedling establishment and seed-set. Annual applications are necessary.

Krenite S® can be used at the rate of 1½ to 2 gallons per acre when leafy spurge is at the true flower growth stage. Results with Krenite S® may be inconsistent and treatment is expensive.

Rodeo® at 1½ pints per acre will provide 80 to 90 percent leafy spurge control when applied from mid-July to mid-September. A non-ionic surfactant approved for aquatic sites should be added to the spray solution for best results. Rodeo® is non-selective and will kill or damage vegetation that is contacted by spray or drift.

Follow manufacturer label recommendations for all herbicides prior to application.

Suggested Management Plan

1. Determine whether leafy spurge is present on land you own or manage by conducting an on-the-ground weed survey. Spot treat, with herbicides, any small, isolated infestations of leafy spurge. Assign high priority to these early detection and treatment activities.

2. Map all infestations, including any that were spot treated. Prioritize infestations that have potential to spread most rapidly or cause the highest economic or ecological losses.

3. Prevent movement of the weed from infested areas into areas free of leafy spurge. Consider livestock, feed, seed and equipment as potential means of spreading infestations. Develop strategies to manage existing infestations. Different sites may require different strategies. Use as many management strategies as possible, integrating them in ways that complement each other. Contain infestations to keep the weed from spreading. Design a management program to gradually eliminate dense infestations while treating satellite infestations. County weed supervisors and county Extension agents can assist you in designing a management program.

4. Manage livestock grazing to increase competitiveness of desirable plants.

5. Monitor and remap leafy spurge annually to determine the impact and effectiveness of management strategies. Adjust strategies based on your findings. Follow-through is essential for successful management of perennial weeds.

6. Keep records to help select economical and effective treatments. Records are also useful to document efforts to meet legal requirements for controlling noxious weeds.

Acknowledgments

Thanks to Bret Olsen, Tom Whitson, Rosie Wallander and Bruce Maxwell for manuscript review.

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Appendix 1. Currently Approved Insect Biocontrol Agents— Habitat Requirements, Biology and Collecting/Releasing Suggestions

Insect	Preferred sites	Generations per year	Location of each life stage and approximate date	Plant part affected	Destructive Stage	Collecting (Stage and Method)	Releasing
Flea Beetles—*Coleoptera: Chrysomelidae*							
Aphthona cyparissiae	Warm, open sunny area, mod. to light spurge density <18 inches rainfall/yr. Sandy loam soils, green needlegrass.	One	**Egg**; lower stem, July–Sept. **Larvae**: root hairs, Aug–May. **Pupae** in soil, May–June. **Adults**: foliage July–Sept.	Root hairs (larvae) and foliage (adults)	Larvae. Adults to lesser extent	Adult, sweepnet. Approx. late June (northern climates)	On foliage
Aphthona czwalinae	Moist, loamy soil (possibly clay), (Possibly on sunny, well-drained, sandy or rocky sites.) Ample humidity. Spurge mixed with other vegetation. No dry or open sites.	One	**Egg**: in soil near stems, July–Sept. **Larvae**: roots, July–early June. **Pupae**: in soil, early June. **Adults**: foliage, mid-June–Sept.	Roots (larvae) and foliage (adults).	Larvae. Adults to lesser extent.	Adult, sweepnet. Approx. early June (northern climates)	On foliage
Aphthona flava	Sunny, south-facing slopes, 18–20 inches rainfall per year. Arrowleaf balsam root plant communities. No clay or acidic soils, no deep shade.	One	**Egg**: plant stem at soil surface, June–Oct. **Larvae:** roots, July–June. **Pupae**: in soil, May–June. **Adults**: foliage, June–Oct .	Roots (larvae); foliage and flowers (adults).	Larvae. Adults to lesser extent.	Adult, sweepnet Approx. late July (northern climates)	On foliage

Aphthona lacertosa	Slightly moist to wet sites, loamy soils, well-developed herbaceous vegetation. Possibly on clay sites. No very dry or flooded sites.	One	**Egg**: in soil near stems, summer. **Larvae**: roots, fall to spring. **Pupae**: in soil, spring. **Adults**: foliage, early summer through fall.	Roots (larvae), foliage and flowers (adults).	Larvae. Adults to lesser extent	Adult, sweepnet. Approx. mid-July (northern climates)	On foliage
Aphthona nigriscutis	Dry sites, soils >60% sand, needle-and-thread or porcupine grasses, flowering spurge <30" tall, <50 stems/yd, (15% + exposed soil.)	One	**Egg**: plant stem, at soil line, June–Aug. **Larvae**: roots, July–spring. **Pupae**: in soil, early spring. **Adults**: foliage, flowers, June–Aug.	Roots (larvae), foliage and flowers (adults).	Larvae. Adults to lesser extent	Adult, sweepnet Approx. early July (northern climates)	On foliage
Stem-boring beetle—*Coleoptera: cerambycidae*							
Oberea erythro-cephala	Sunny sites, near streams and rivers, trees. Shady sites acceptable.	One. In colder climates may take two years to mature.	**Egg**: inside stem, late June–mid July. **Larvae**: inside stem, root crown, July–May. **Pupae**: in crown, May–June. **Adults**: free-moving, June–July.	Stem and crown, causing above ground portion to wilt and die.	Larvae. Adults some feeding and girdling of stems.	Adult, sweepnet or by hand. Late June to mid-July (northern climates)	On spurge plants.